

Markscheme

May 2017

Chemistry

Higher level

Paper 2

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Question			Answers	Notes	Total
1.	a	i	$n(\text{Ag}) = \frac{3.275 \text{ g}}{107.87 \text{ g mol}^{-1}} \Rightarrow 0.03036 \text{ «mol»}$ <p>AND</p> $n(\text{O}) = \frac{3.760 \text{ g} - 3.275 \text{ g}}{16.00 \text{ g mol}^{-1}} = \frac{0.485}{16.00} \Rightarrow 0.03031 \text{ «mol»} \checkmark$ $\frac{0.03036}{0.03031} \approx 1 \text{ / ratio of Ag to O approximately } 1 : 1, \text{ so}$ <p>AgO ✓</p>	<p>Accept other valid methods for M1.</p> <p>Award [1 max] for correct empirical formula if method not shown.</p>	2
1	a	ii	<p>temperature too low</p> <p>OR</p> <p>heating time too short</p> <p>OR</p> <p>oxide not decomposed completely ✓</p> <p>heat sample to constant mass «for three or more trials» ✓</p>	<p>Accept “not heated strongly enough”.</p> <p>If M1 as per markscheme, M2 can only be scored for constant mass technique.</p> <p>Accept “soot deposition” (M1) and any suitable way to reduce it (M2).</p> <p>Accept “absorbs moisture «from atmosphere» (M1) and “cool in dessicator” (M2).</p> <p>Award [1 max] for reference to “impurity” AND design improvement.</p>	2
1	b		<p>A_r closer to 107/less than 108 «so more ^{107}Ag»</p> <p>OR</p> <p>A_r less than the average of (107 + 109) «so more ^{107}Ag» ✓</p>	<p>Accept calculation that gives greater than 50% ^{107}Ag.</p>	1

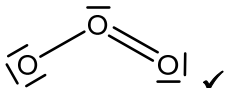
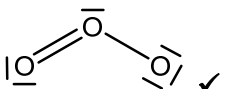
Question			Answers	Notes	Total		
1	c	i	<div>Flask containing</div>	<div>Colour of solution</div>	<div>Product formula</div>	<div>Do not accept name for the products. Accept “Na⁺ + OH[–]” for NaOH. Ignore coefficients in front of formula.</div>	3
			Na ₂ O	blue	NaOH ✓		
			P ₄ O ₁₀	AND yellow ✓	H ₃ PO ₄ ✓		
1	c	ii	<div>«molten» Na₂O has mobile ions/charged particles AND conducts electricity ✓ «molten» P₄O₁₀ does not have mobile ions/charged particles AND does not conducts electricity/is poor conductor of electricity ✓</div>			<div>Do not award marks without concept of mobile charges being present. Award [1 max] if type of bonding or electrical conductivity correctly identified in each compound. Do not accept answers based on electrons. Award [1 max] if reference made to solution.</div>	2
1	d		<div>electrons in discrete/specific/certain/different shells/energy levels ✓ energy levels converge/get closer together at higher energies OR energy levels converge with distance from the nucleus ✓</div>			<div>Accept appropriate diagram for either M1, M2 or both. Do not give marks for answers that refer to the lines in the spectrum.</div>	2

Question			Answers	Notes	Total
2.	a	i	$\text{Sn}^{2+}(\text{aq}) \rightarrow \text{Sn}^{4+}(\text{aq}) + 2\text{e}^-$ ✓	Accept equilibrium sign. Accept $\text{Sn}^{2+}(\text{aq}) - 2\text{e}^- \rightarrow \text{Sn}^{4+}(\text{aq})$	1
2	a	ii	$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 3\text{Sn}^{2+}(\text{aq}) \rightarrow 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l}) + 3\text{Sn}^{4+}(\text{aq})$ ✓	Accept equilibrium sign.	1
2	a	iii	$\ll [\text{K}_2\text{Cr}_2\text{O}_7] = \frac{13.239 \text{ g}}{294.20 \text{ g mol}^{-1} \times 0.100 \text{ dm}^3} \Rightarrow 0.450 \ll \text{mol dm}^{-3} \gg$ ✓		1
2	a	iv	$n(\text{Sn}^{2+}) = \ll 0.450 \text{ mol dm}^{-3} \times 0.01324 \text{ dm}^3 \times \frac{3 \text{ mol}}{1 \text{ mol}} \Rightarrow 0.0179 \ll \text{mol} \gg$ ✓ $\ll [\text{Sn}^{2+}] = \frac{0.0179 \text{ mol}}{0.0100 \text{ dm}^3} \Rightarrow 1.79 \ll \text{mol dm}^{-3} \gg$ ✓	Award [2] for correct final answer.	2
2	a	v	hydroxyl/OH OR aldehyde/CHO ✓	Accept “hydroxy/alcohol” for “hydroxyl”. Accept amino/amine/ NH_2 .	1
2	b	i	$\ll E^\ominus \Rightarrow +0.85 \ll \text{V} \gg$ ✓	Accept 0.85 V.	1
2	b	ii	$\Delta G^\ominus \ll = -nFE^\ominus \gg = -2 \ll \text{mol e}^- \gg \times 96500 \ll \text{C mol}^{-1} \gg \times 0.85 \ll \text{V} \gg$ ✓ $\ll \Delta G^\ominus \Rightarrow -164 \ll \text{kJ} \gg$ ✓	Accept “ $\ll + \gg 164 \ll \text{kJ} \gg$ ” as question states energy released. Award [1 max] for “+” or “–” 82 «kJ». Do not accept answer in J.	2
2	b	iii	incompletely filled d-orbitals ✓ colour depends upon the energy difference between the split d-orbitals ✓ variable/multiple/different oxidation states ✓ different «nature/identity of» ligands ✓ different number of ligands ✓		3 max

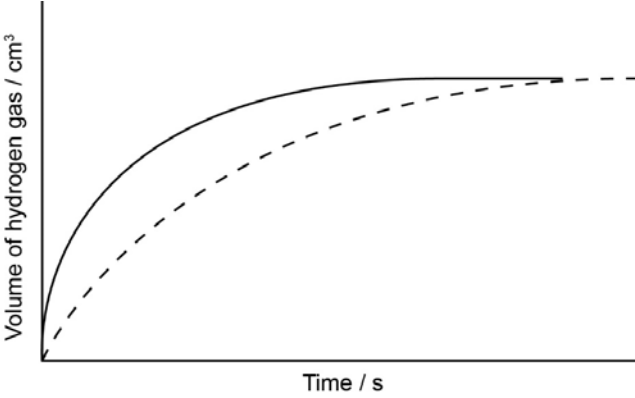
Question			Answers	Notes	Total
2	c		<p>Zn/zinc is a stronger reducing agent than Fe/iron</p> <p>OR</p> <p>Zn/zinc is oxidized instead of Fe/iron</p> <p>OR</p> <p>Zn/zinc is the sacrificial anode ✓</p>	<p><i>Accept “Zn is more reactive than Fe”.</i></p> <p><i>Accept “Zn oxide layer limits further corrosion”.</i></p> <p><i>Do not accept “Zn layer limits further corrosion”.</i></p>	1

Question			Answers	Notes	Total
3.	a	i	$K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]} \checkmark$		1
3	a	ii	<p>decrease in temperature \checkmark</p> <p>endothermic «reaction» AND «equilibrium» shifts to the left/reactants OR endothermic «reaction» AND K_c decreases OR endothermic «reaction» AND concentration of PCl_5 increased/concentration of PCl_3 and Cl_2 decreased OR «equilibrium» shifts in the exothermic direction \checkmark</p>	<p>Do not accept “temperature change”.</p> <p>Accept “ΔH positive” in place of “endothermic”.</p> <p>Accept “products” instead of “PCl_3 and Cl_2”.</p>	2
3	b		<p>Lewis structure:</p> <pre> Cl—P—Cl Cl </pre> <p style="text-align: right;">\checkmark</p> <p>Molecular geometry: trigonal/triangular pyramidal \checkmark</p> <p>Bond angles: $< 109.5^\circ \checkmark$</p>	<p>Penalize missing lone pairs once only between this question and 4(b)(ii). Accept any combination of lines, dots or crosses to represent electrons.</p> <p>Do not apply ECF.</p> <p>Do not accept answer equal to or less than 90°. Literature value is 100.1°.</p>	3

Question			Answers	Notes	Total
4.	a	i	triple bond in nitrogen «molecule» AND single bond in hydrazine ✓ triple bond is stronger than single bond OR more shared «pairs of» electrons make bond stronger/attract nuclei more ✓	Accept bond enthalpy values from data booklet (158 and 945 kJ mol ⁻¹).	2
4	a	ii	hydrogen bonding «between molecules, dinitrogen tetraoxide does not» ✓		1
4	a	iii	N ₂ H ₄ : -2 AND N ₂ O ₄ : +4 ✓		1
4	a	iv	N ₂ H ₄ AND oxidized/oxidation state increases OR N ₂ H ₄ AND loses hydrogen OR N ₂ H ₄ AND reduces/removes oxygen from N ₂ O ₄ ✓	Accept “N ₂ H ₄ AND gives electrons «to N ₂ O ₄ »”.	1

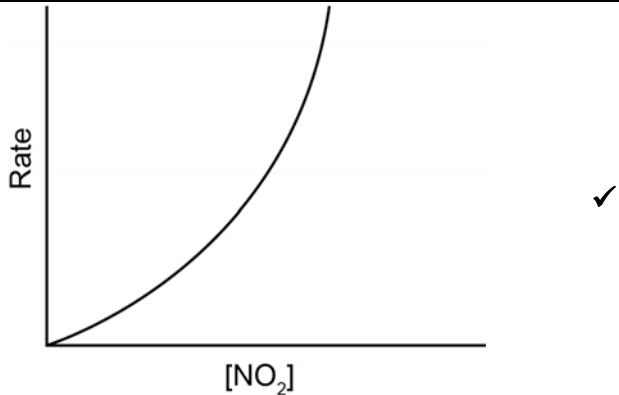
Question			Answers	Notes	Total
4	b	i	<p>lone pair on p orbital «of O atom» overlaps/delocalizes with pi electrons «from double bond» ✓</p> <p>both O–O bonds have equal bond length</p> <p>OR</p> <p>both O–O bonds have same/1.5 bond order</p> <p>OR</p> <p>both O–O are intermediate between O–O AND O=O ✓</p> <p>both O–O bonds have equal bond energy ✓</p>	Accept “p/pi/π electrons are delocalized/not localized”.	3
4	b	ii	<p>ALTERNATIVE 1:</p>  <p>FC: –1 AND +1 AND 0 ✓</p> <p>ALTERNATIVE 2:</p>  <p>FC: 0 AND +1 AND –1 ✓</p>	<p>Accept any combination of lines, dots or crosses to represent electrons.</p> <p>Do not accept structure that represents 1.5 bonds.</p> <p>Do not penalize missing lone pairs if already penalized in 3(b).</p> <p>If resonance structure is incorrect, no ECF.</p> <p>Any one of the structures with correct formal charges for [2 max].</p>	2

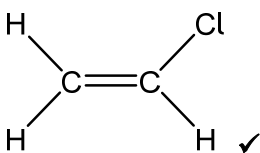
Question			Answers	Notes	Total
4	c		<p>Any two of:</p> <p>IE₄: electron in lower/inner shell/energy level OR IE₄: more stable/full electron shell ✓</p> <p>IE₄: electron closer to nucleus OR IE₄: electron more tightly held by nucleus ✓</p> <p>IE₄: less shielding by complete inner shells ✓</p>	Accept “increase in effective nuclear charge” for M2.	2 max
4	d	i	<p>$Q_c = \frac{0.10}{0.52^2} \Rightarrow 0.37$ ✓</p> <p>reaction proceeds to the left/NO₂(g) «until $Q = K_c$» OR reverse reaction «favoured» ✓</p>	Do not award M2 without a calculation for M1 but remember to apply ECF.	2
4	d	ii	<p>$\Delta G = 0$ ✓</p> <p>reaction at equilibrium OR rate of forward and reverse reaction is the same OR constant macroscopic properties ✓</p>		2

Question			Answers	Notes	Total
5.	a	i	concentration of acid decreases OR surface area of magnesium decreases ✓	Accept “less frequency/chance/rate/probability/likelihood of collisions”. Do not accept just “less acid” or “less magnesium”. Do not accept “concentration of reagents decrease”.	1
5	a	ii	 <p>curve starting from origin with steeper gradient AND reaching same maximum volume ✓</p>		1
5	b	i	«rate =» $k [\text{NO}_2]^2$ ✓	Accept $\text{rate} = k [\text{NO}_2]^2 [\text{CO}]^0$.	1
5	b	ii	«step» I AND CO does not appear in the rate law expression OR «step» I AND only «2 molecules of» NO_2 appears in rate expression ✓	Do not allow ECF from (i).	1

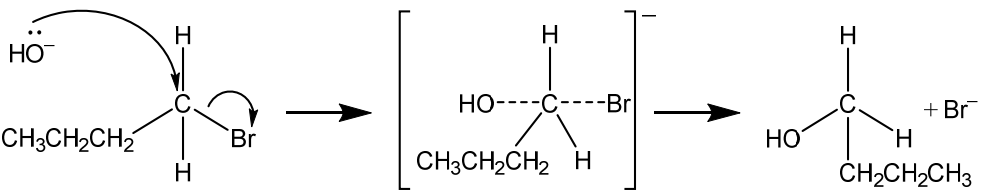
(continued...)

(Question 5b continued)

Question			Answers	Notes	Total
5	b	iii	«IR or UV-vis» spectroscopy OR colorimetry OR colour change «over time» ✓	Accept GC/gas chromatography.	1
5	b	iv	« $E_{a(\text{rev})} = 226 + 132 \Rightarrow 358$ «kJ» ✓	Do not accept –358.	1
5	b	v		Curve must go through origin.	1
5	c		activation energy is independent of temperature ✓	Accept “no relationship”.	1
5	d		$2\text{NO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{HNO}_3(\text{aq}) + \text{HNO}_2(\text{aq})$ OR $4\text{NO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g}) \rightarrow 4\text{HNO}_3(\text{aq})$ ✓	Accept ionized forms of the acids.	1

Question			Answers	Notes	Total
6.	a		<p><i>Initiation:</i></p> $\text{Cl}-\text{Cl} \rightarrow \text{Cl}\cdot + \text{Cl}\cdot \checkmark$ <p><i>Propagation:</i></p> $\text{Cl}\cdot + \text{CH}_4 \rightarrow \text{Cl}-\text{H} + \cdot\text{CH}_3 \checkmark$ $\text{Cl}-\text{Cl} + \cdot\text{CH}_3 \rightarrow \text{Cl}-\text{CH}_3 + \text{Cl}\cdot \checkmark$	<p>Do not penalize missing electron dot on radicals if consistent throughout.</p> <p>Accept Cl_2, HCl and CH_3Cl without showing bonds.</p> <p>Do not accept hydrogen radical, $\text{H}\cdot$ or H, but apply ECF to other propagation steps.</p>	3
6	b		$\llcorner \Delta H^\ominus \rceil = -82.0 \text{ «kJ»} - 92.3 \text{ «kJ»} - (-74.0 \text{ «kJ»}) \checkmark$ $\llcorner \Delta H^\ominus \rceil = -100.3 \text{ «kJ»} \checkmark$	Award [2] for correct final answer.	2
6	c		$\text{H}_2\text{C}=\text{CHCl}$ <p>OR</p> 	<p>Accept "CH_2CHCl" or "CHClCH_2".</p> <p>Do not accept "$\text{C}_2\text{H}_3\text{Cl}$".</p>	1

Question			Answers	Notes	Total
7.	a	i	Number of hydrogen environments: 3 ✓ Ratio of hydrogen environments: 2:3:9 ✓ Splitting patterns: «all» singlets ✓	Accept any equivalent ratios such as 9:3:2. Accept “no splitting”.	3
7	a	ii	carbonyl OR C=O ✓	Accept “ketone” but not “aldehyde”.	1
7	a	iii	$ \begin{array}{c} \text{CH}_3 \\ \\ \text{H}_3\text{C}-\text{C}-\text{CH}_2-\text{C}(=\text{O})-\text{CH}_3 \\ \\ \text{CH}_3 \end{array} $ ✓✓	Accept (CH ₃) ₃ CCH ₂ COCH ₃ . Award [1] for any aldehyde or ketone with C ₇ H ₁₄ O structural formula.	2
7	b	i	hexane AND hex-1-ene ✓	Accept “benzene AND hexane AND hex-1-ene”.	1
7	b	ii	CH ₃ CH ₂ CH ₂ CH ₂ CHBrCH ₃ ✓	Accept displayed formula but not molecular formula.	1
7	c	i	Reagents: «concentrated» sulfuric acid AND «concentrated» nitric acid ✓ Name of mechanism: electrophilic substitution ✓		2
7	c	ii	benzene has «delocalized» π bonds «that are susceptible to electrophile attack» AND alkanes do not ✓	Do not accept “benzene has single and double bonds”.	1

Question	Answers	Notes	Total
<p>7</p> <p>d</p>	 <p>curly arrow going from lone pair/negative charge on O in OH^- to C ✓</p> <p>curly arrow showing Br leaving ✓</p> <p>representation of transition state showing negative charge, square brackets and partial bonds ✓</p>	<p>Accept OH^- with or without the lone pair.</p> <p>Do not allow curly arrows originating on H in OH^-.</p> <p>Accept curly arrows in the transition state.</p> <p>Do not penalize if HO and Br are not at 180°.</p> <p>Do not award M3 if OH–C bond is represented.</p> <p>Award [2 max] if wrong isomer is used.</p>	<p>3</p>

Question			Answers	Notes	Total				
8.	a	i	H ₂ O/water ✓	Accept “hydroxide ion/OH ⁻ ”.	1				
	a	ii	<table><tr><th>Acid</th><th>Base</th></tr><tr><td>HOCl AND OR H₂O AND</td><td>OCl⁻ OH⁻ ✓</td></tr></table>	Acid	Base	HOCl AND OR H ₂ O AND	OCl ⁻ OH ⁻ ✓		1
Acid	Base								
HOCl AND OR H ₂ O AND	OCl ⁻ OH ⁻ ✓								
	b	i	«0.100 mol dm ⁻³ × 0.0250 dm ³ » = 0.00250 «mol» ✓		1				
	b	ii	« $M = \frac{0.510 \text{ g}}{0.00250 \text{ mol}} \Rightarrow 204 \text{ «g mol}^{-1}\text{»}$ » ✓		1				
	b	iii	«1.00 × 10 ⁻¹⁴ = [H ⁺] × 0.100» 1.00 × 10 ⁻¹³ «mol dm ⁻³ » ✓		1				
	b	iv	weak AND pH at equivalence greater than 7 OR weak acid AND forms a buffer region ✓		1				
	b	v	calorimetry OR measurement of heat/temperature OR conductivity measurement ✓	Accept “indicator” but not “universal indicator”.	1				
	b	vi	«pK _a = pH at half-equivalence ⇒ 5.0		1				

Question			Answers	Notes	Total
	c		$K_a = 10^{-4.35} / 4.46683 \times 10^{-5} \checkmark$ $[H_3O^+] = \sqrt{4.46683 \times 10^{-5} \times 1.60 \times 10^{-3}} / \sqrt{7.1469 \times 10^{-8}} / 2.6734 \times 10^{-4} \text{ «mol dm}^{-3}\text{»} \checkmark$ $pH = \text{«} -\log \sqrt{7.1469 \times 10^{-8}} \Rightarrow 3.57 \checkmark$	<p><i>Award [3] for correct final answer to two decimal places.</i></p> <p><i>If quadratic equation used, then:</i></p> <p>$[H_3O^+] = 2.459 \times 10^{-4} \text{ «mol dm}^{-3}\text{»}$</p> <p><i>and pH = 3.61</i></p>	3

Question			Answers	Notes	Total
9.	a	i	$\Delta H = 177.0 - \frac{189.2}{2} - 285.5 \text{ «kJ» } \checkmark$ $\text{«}\Delta H \text{»} = -203.1 \text{ «kJ» } \checkmark$	<p>Accept other methods for correct manipulation of the three equations.</p> <p>Award [2] for correct final answer.</p>	2
	a	ii	$203.1 \text{ «kJ»} = 0.850 \text{ «kg»} \times 4.18 \text{ «kJ kg}^{-1} \text{ K}^{-1}\text{»} \times \Delta T \text{ «K»}$ <p>OR</p> $\text{«}\Delta T \text{»} = 57.2 \text{ «K» } \checkmark$ $\text{«}T_{\text{final}} = (57.2 + 21.8)^{\circ}\text{C} \text{»} = 79.0^{\circ}\text{C} \text{»} / 352.0 \text{ «K»} \checkmark$ <p>If 200.0 kJ was used:</p> $200.0 \text{ «kJ»} = 0.850 \text{ «kg»} \times 4.18 \text{ «kJ kg}^{-1} \text{ K}^{-1}\text{»} \times \Delta T \text{ «K»}$ <p>OR</p> $\text{«}\Delta T \text{»} = 56.3 \text{ «K» } \checkmark$ $\text{«}T_{\text{final}} = (56.3 + 21.8)^{\circ}\text{C} \text{»} = 78.1^{\circ}\text{C} \text{»} / 351.1 \text{ «K»} \checkmark$	<p>Award [2] for correct final answer.</p> <p>Accept two, three or four significant figures.</p> <p>Unit, if specified, must be consistent with value stated.</p>	2
	b	i	$\text{«}\Delta S^{\ominus} \text{»} = 270 \text{ «J K}^{-1} \text{ mol}^{-1}\text{»} - 267 \text{ «J K}^{-1} \text{ mol}^{-1}\text{»} - 131 \text{ «J K}^{-1} \text{ mol}^{-1}\text{» } \checkmark$ $\text{«}\Delta S^{\ominus} \text{»} = -128 \text{ «J K}^{-1} \text{ mol}^{-1}\text{» } \checkmark$	<p>Award [2] for correct final answer.</p>	2
	b	ii	<p>«non spontaneous if» $\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus} > 0$</p> <p>OR</p> $\Delta H^{\ominus} > T\Delta S^{\ominus} \checkmark$ $\text{«}T \text{ above» } \frac{-124.4 \text{ «kJ mol}^{-1}\text{»}}{-0.128 \text{ «kJ K}^{-1} \text{ mol}^{-1}\text{»}} = 972 \text{ «K» } \checkmark$	<p>Award [2] for correct final answer.</p> <p>Accept 699 °C.</p> <p>Do not award M2 for any negative T value.</p>	2